Monitoring the Dynamic Characteristics of a Concrete Arch Bridge in Public Service Using a wireless CUMS

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Abstract

The purpose of the paper is to develop a health monitoring system using wireless CUMS(Custom-made Unified Measurement System) for a concrete arch bridge in public service. This particular health monitoring system was specially designed to support signal processing of each different type of transmitter and also develop a user interface where the designed system can be utilized for the measurement and maintenance of structures. In order to develop the health monitoring system which would be applicable to the long-term monitoring system for bridges, first the dynamic characteristics of bridges need to be identified. So after placing the wireless CUMS to acquire the acceleration to a concrete arch bridge in public service, we analyzed its dynamic characteristics from the real-time data of vibration which was made by the traffic load. For the analysis of data, CPSD and NEXT & ERA algorithm were employed. The following analytic results were compared to those of the FE analysis, by which the wireless CUMS proved to be valid.

1. Introduction

These days many methods have been developed to maintain construction structures in real time using measuring devices[1]. Most of them employed a particular kind of measuring device, and were limited to the evaluation of the health of structures or to a mere reference. For example, a study was done using vibration to maintain structures and detect structural damages [2,3]. It applied ambient vibration technique which used natural vibration, also eigenvalue decomposition method which was an algorithm suitable for the analysis of dynamic characteristics of structures, and finally employed an acceleration sensor to measure vibration. This was just one of many studies of this type[4~7].

However, it has become necessary to use more than one kind of measuring devices and various kinds of damage evaluation methods as well. The employment of different types of measuring devices will enable us to detect damages in a variety of ways and contribute to the development of a real-time monitoring system. For this purpose, CUMS(Custom-made

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Unified Measurement System)was developed in this research. It is to transfer data wirelessly and have the user interphase where the damage estimation in real time is possible(5-7). The CUMS will be applied to the monitoring of a concrete arch bridge in public service, by which the structural characteristics of the bridge was analyzed and evaluated. For the evaluation, we obtained the real-time data about the vibration which was created by traffic load, and analyzed the dynamic characteristics of the bridge in real-time. For the analysis of the data, NExT & ERA algorithm were employed, and the results were compared with those of FE analysis of the same bridge. So the performance of CUMS proved to be useful.

2. The Composition of Wireless CUMS Measurement Monitoring System

2.1 The Composition and Principle of Wireless Measurement System

The measuring system developed here in this research was designed to evaluate the health of structures on the basis of structural performance. This measuring system are supposed to function in three ways; that is, it is composed of three parts: CUMS(Custom-made Unified Measurement System), IDPA(Intelligent Data Processing Algorithm), and MIT(Multidisciplinary Intercrossing Technique).

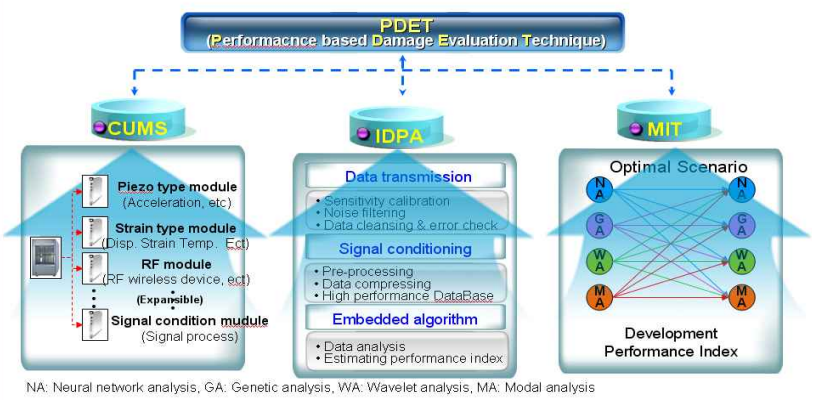


Fig. 1 The Composition of Measuring System

Here, the CUMS is to select an optimal measuring device out of many different types of measuring devices, and compose a module by which a user-friendly measuring system can be composed. The CUMS is not only to measure data but also to manage them through the signal processing called IDPA. Those data are used in MIT module which is to define an optimal algorithm for the target structure and to evaluate its health. This evaluation system is the PDET (Performance based Damage Evaluation Technique). It is the system where users can select a signal and damage estimation method which they want to

measure for health monitoring, and accordingly select a suitable sensor and evaluation method.

2.2 Wireless Sensor System

Employing the bluetooth which is a cutting edge of wireless communication technology, this system is a wireless acceleration sensor system which speedily transfers acceleration signals without noise. This system is composed of four sensor nodes each of which is equipped with two poled MEMS acceleration sensor, 16bit A.D converter, 8bit microcontroller, bluetooth communication module, and Li-ion charge module, not only acquiring acceleration data but also enabling us to make a decision on the basis of embedded algorithm as in the Fig 2. The wireless acceleration sensor is to measure the range of ±1.2g, less than 50Hz, about 0.5mg RMS in signal resolution including the level of noise, and 1.2km in maximum distance .

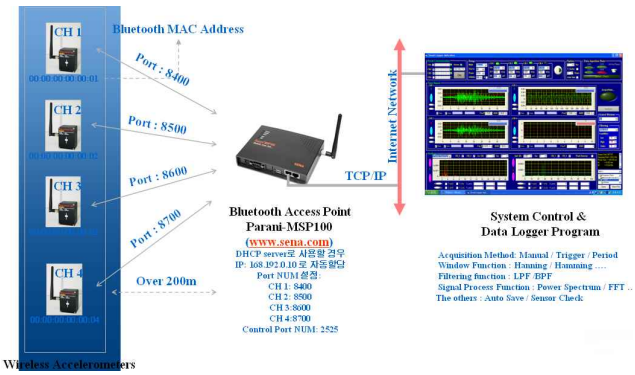


Fig. 2 Configuration of the Sensor System

2.3 The Target Bridge and Measurement

The target bridge for experiment is a first class concrete arch one which is twenty years old located in one of the state roads. Its length is 204m, its load is designed to be DB24, its maximum span is 60m, its height is 30m, its width 10.5m. As a measuring system, three sensors were placed in evenly spaced on the 60m site as shown in Fig. 3, and a sensor was placed in the center of the opposite side. As a method of acquiring data, a trigger method was taken, acquiring 4092 data for 27.28 seconds from four channels by the 150Hz sampling when measuring more than 1mg.

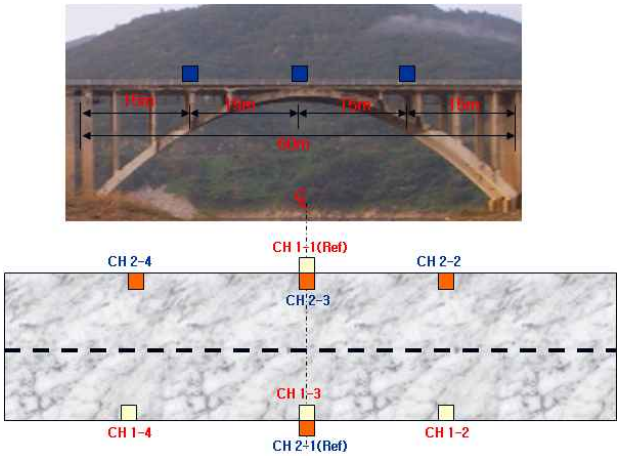


Fig. 3 Sensor Location of the Bridge

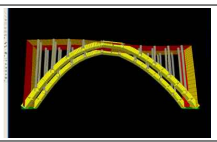
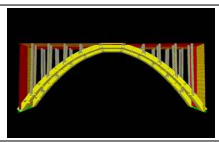
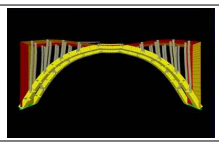
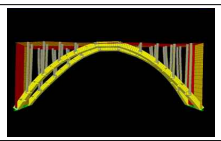
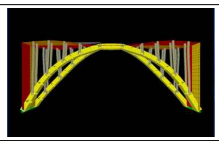
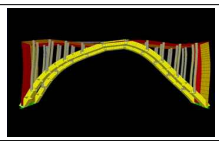
Item	Bending Mode	Bending Mode	Bending Mode
Mode shape			
Natural Frequence	2.0472Hz	3.6941Hz	5.1534Hz
Item	Twist Mode	Twist Mode	Bending Mode
Mode shape			
Natural Frequence	7.5675Hz	7.6936Hz	8.2529Hz

Table 1. Results of Modal Analysis of the Bridge

The results of approximate modal analysis about the target bridge are like in Table 1.

2.4 The Data Analysis Approach

The data in this paper were acquired by ambient vibration data which is random data. One of the method to analysis the dynamic characteristics of structures is NExT & ERA algorithm which estimates only with natural excitation. The NExT & ERA algorithm is the one that derives the number of vibration and the modal feature by dismantling a spectrum of cross correlation function of data on the measuring site using Singular Value Decomposition(SVD) (이우상, et al 2008). Typical Cross Power Spectrum(CPS) in time domain and frequency domain, and one of cross correlation function from acceleration data as shown in Fig 4. Dynamic characteristics of the bridge structure were analyzed from those acceleration data using NExT ERA method.

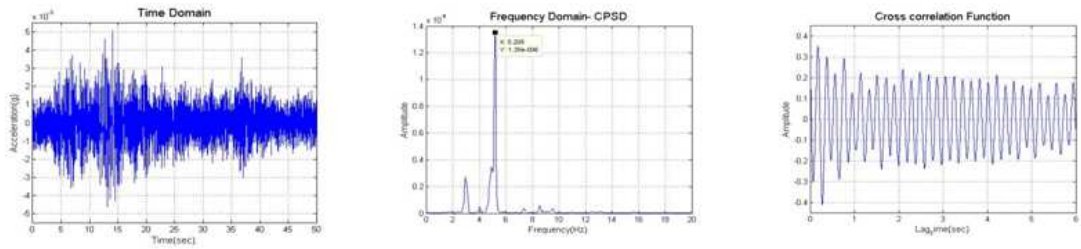


Fig 4. Typical time domain Data, CPSD, and CCF Data

And the results of data from experimental test and FE analysis show good agreement as shown in Table 2. Real time ambient vibration response acquired from smart wireless measurement system were used to produce these results of the bridge structure.

Table 2. The Results of Natural Frequence of the Bridge Structure

Item	1st Bending Mode	2nd Bending Mode	3rd Bending Mode	4th Bending Mode
FE Analysis	2.047Hz	5.153Hz	8.253Hz	9.353Hz
NExT&ERA	2.167Hz	5.187Hz	8.885Hz	9.639Hz

3. Conclusion

In this paper, the proposed measuring system(CUMS) has been developed to evaluate the health of structures on the basis of structural performance. This measuring system are composed of three parts: CUMS(Custom-made Unified Measurement System), IDPA(Intelligent Data Processing Algorithm), and MIT(Multidisciplinary Intercrossing Technique). Using those equipments we experimented on a bridge in public service. The result of the experiment showed that when it was compared to that of FE analysis they coincided each other within the error rate of 4% at maximum. Finally it was proved that the measuring system developed here was effective in measuring the characteristics of structures and eventually would contribute to the development of long-term monitoring system.

Acknowledgement

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